

Luminosity distance in GX cosmological models

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Summary. — We derive luminosity distance equation in Gurzadyan-Xue cosmological models and compared it with available supernovae and radio galaxies data sets. We found that the luminosity distance does not depend explicitly the speed of light and the gravitation constant, and depends only on the matter parameter (GX-invariant) and curvature.

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The formula for dark energy, derived by Gurzadyan and Xue [1] defines a relation between the speed of light c , the gravitational constant G and the scale factor a of the Universe

$$(1) \quad \rho_{GX} = \frac{\pi}{8} \frac{\hbar c}{L_p^2} \frac{1}{a^2} = \frac{\pi}{8} \frac{c^4}{G} \frac{1}{a^2},$$

where \hbar is the Planck's constant, L_p is the Planck's length. The formula does not contain any free parameters as in many approaches to the cosmological constant problem (see e.g. [16]).

One of possible implications of this formula is variation of fundamental physical constants with time, approach rather popular in the current literature (see e.g. [6]).

Based on the scaling (1) one may consider a set of cosmological models [3]. In spite of difference of cosmological equations in each model, some interesting similarities were found, in particular invariants, explaining underlying symmetry in the models.

In this paper we compare GX models with supernovae and radio galaxies data sets. We perform likelihood analysis and provide best-fit values of the density parameter for all models.

Cosmological equations for GX models were derived in [4] and read

$$(2) \quad \begin{aligned} \dot{\mu} + 3H\mu &= -\dot{\mu}_\Lambda + (\mu + \mu_\Lambda) \left(\frac{2\dot{c}}{c} - \frac{\dot{G}}{G} \right) \\ H^2 + \frac{kc^2}{a^2} - \frac{\Lambda}{3} &= \frac{8\pi G}{3} \mu. \end{aligned}$$

Here μ is mass density, H is Hubble constant and $k = \pm 1, 0$ is the spatial curvature. The representation of the Hubble constant in the terms of GX invariants is derived in [14]

$$(3) \quad H(a) = \frac{c(a)}{a} \sqrt{\alpha \frac{a_0}{a} + \beta},$$

where $\alpha = \frac{8\pi b_m^{GX}}{3a_0}$, $\beta = \pi^2 - k$. The luminosity distance $d_L(z)$ as a function of redshift z is defined as [15]

$$(4) \quad \begin{aligned} d_L(z) &= a_0 f_k(\kappa_s)(1+z), \\ \kappa_s &= \frac{1}{a_0 H_0} \int_0^z \frac{c(\dot{z})}{h(\dot{z})} d\dot{z}, \\ h(z) &= \frac{H(z)}{H_0}, \quad 1+z = \frac{a_0}{a} \end{aligned}$$

where κ_s is normalized distance; the subscript 0 denotes the value of each quantity today. The function $f_k(\kappa_s)$ is

$$f_k(x) = \begin{cases} \sin(x), & k = 1 \\ x, & k = 0 \\ \sinh(x), & k = -1 \end{cases}$$

Using (3) and (4) one can find the luminosity distance and distance modulus for GX models

$$(5) \quad d_L(z) = a_0(1+z)f_k \left(\ln \left| \frac{\sqrt{\frac{\alpha}{\beta}(z+1)+1}-1}{\sqrt{\frac{\alpha}{\beta}+1}-1} \frac{\sqrt{\frac{\alpha}{\beta}+1}+1}{\sqrt{\frac{\alpha}{\beta}(z+1)+1}+1} \right| \right)$$

$$(6) \quad d_M(z) = 5 \log \left(\frac{d_L(z)}{10 \text{ pc}} \right).$$

The observation data set consists of 71 supernovae from the Supernova Legacy Survey [9], 157 ‘‘Gold’’ supernovae of [10], 16 ‘‘Gold’’ high redshift supernovae from the Hubble Space Telescope (HST) [11] and 20 radio galaxies of [12]. In total there are 264 sources with redshifts between zero and 1.8. We have compared GX models with observational data using standard least square technique.

$$(7) \quad \chi^2 = \sum_{i=1}^{264} \left(\frac{d_M^{Obs}(z_i) - d_M^{Th}(z_i)}{\sigma_i} \right)^2$$

here $d_{MObs}(z_i)$, $d_{MTh}(z_i)$, σ_i are observed, theoretical values of distance modulus and errors of data at point z_i , respectively. Results of the fit for models are shown in fig. 1. As one can see from 1 the best fits depends on curvature k . The fit is better with smaller Ω_m . Since the character of solutions changes for $\Omega_m < \Omega_{sep}$ [5] for GX models we took Ω_{sep} as a best fit.

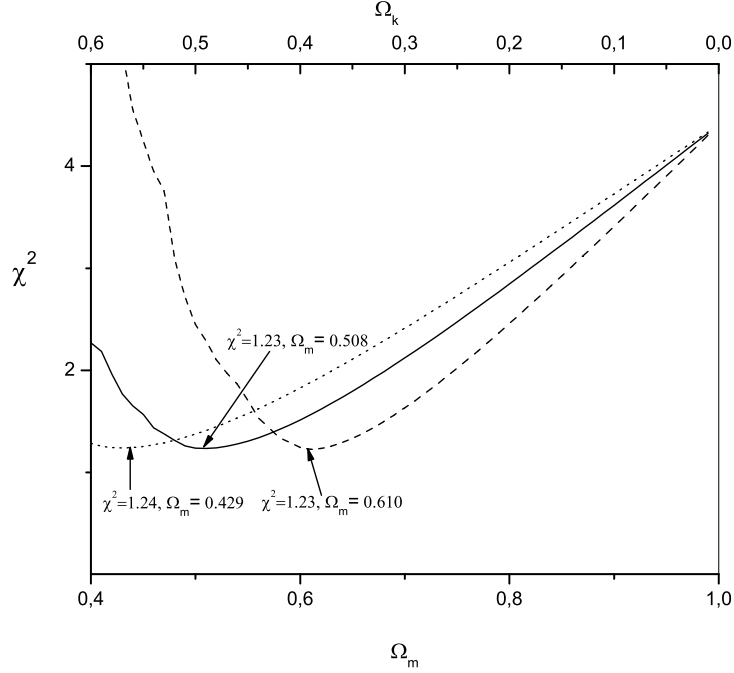


Figure 1. – χ^2 depending on Ω_m for GX models. $k = 0, 1, -1$ for thick, dash and dot lines respectively. The points of minima are 0.43, 0.51, 0.61 for $k = 0, 1, -1$ respectively.

To conclude, we have derived the luminosity distance in GX models in terms of GX invariants. It shows the important role of GX invariants as general tools to examine the features of the cosmological models with Gurzadyan-Xue dark energy. We performed likelihood analysis and provided best-fit values of the density parameter for all models. We found that likelihood for all GX models coincide. This is due to the fact that the luminosity distance depends only on the matter density and the curvature.

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